Explanation of the anomalous acceleration of a free moving body in the frame of extended space model

D. Yu. Tsipenyuk*
General Physics Institute of the Russian Academy of Sciences
119991, Russia, Moscow, Vavilova str.38
and
W. B. Belayev†
Center for Relativity and Astrophysics,
185 Box , 194358, Sanct-Petersburg, Russia

February 7, 2008

Abstract

We consider (1+4) generalization of classical electrodynamics including gravitation field. With this approach it is assumed a presence of an extra component of extended field stress tensor, whose physical interpretation is based on necessity to obtain Newton gravity law as particular case.

In model analyzed in present work mass of having in 4D a rest mass particle moves in five-dimensional space-time along fifth coordinate with light velocity and its electric charge is a stationary value in additional dimension. Generalized gravity law that is obtained from extended Maxwell equations confirmed by existence of variable component of Pioneer 10 additional acceleration, whose analyze is made in frame of this model.

Generalization of the special theory of relativity (SR) for 5-dimensional extended space with the metric (+; -, -, -, -) has been offered in the papers [1-11]. In particular, this model of extended space (ESM) allows integrating electromagnetic and gravitational interactions.

In ESM interval S (which already exists in the (1 + 3) -dimensional Minkowski space $M(T;\vec{X})$) is used as the 5-th additional coordinate of the (1 + 4) -dimensional extended space $G(T;\vec{X};S)$:

$$S^2 = (ct)^2 - x^2 - y^2 - z^2. \tag{1}$$

Interval S is conserved at common Lorentz transformations in the Minkowski space $M(T;\vec{X})$ but varies at turns in the extended space $G(T;\vec{X};S)$. Thus, Minkowski space $M(T;\vec{X})$ is a cone in extended space $G(T;\vec{X};S)$. A stable particle, which has a rest mass in the 4-D Minkowski space, has not a rest mass in 5-D space independence from turns in this 5-D space. This particle moves along fifth coordinate with speed of light

*e-mail:tsip@kapella.gpi.ru
†e-mail:dscal@ctinet.ru

(in case of zero 5-interval). Such approach corresponds to the Kaluza-Klein theory [12] and theory of induced substance [13].

Other version will be existence of a particle in 5-D space, which can be stationary in this space and has a rest mass (nonzero 5-interval). Not limiting a generality, we will consider version with a zero 5-interval.

The various details of the ESM structure were considered in papers [4-10], and also repeatedly were reported on various scientific conferences [11, 14, 15, 16]. The main difference ESM from SR is that ESM allows to study processes at which mass m of a particle is an alternative value. In the ESM model mass of a particle is a component of 5-vector in space $G(T;\vec{X};S)$ other components are energy and momentum of a particle. Thus, mass of a particle varies at transformations in $G(T;\vec{X};S)$.

In articles [1, 8] (see also [4, 15]) in the ESM were constructed:

5-vector potential -

$$(\varphi,\vec{A},A_4)=(A_T,A_x,A_y,A_z,A_S), \tag{2}$$

the stress 5x5 tensors -

$$F_{ik}=\frac{\partial A_i}{\partial x_k}-\frac{\partial A_k}{\partial x_i} \tag{3}$$

and energy-momentum-mass tensors -

$$T^{ik}=\frac{1}{4\pi}(-F^{il}F_l^k+\frac{1}{4}g^{il}F_{lm}F^{lm});\ i,k=0,1,2,3,4 \tag{4}$$

Here $\|g^{ik}\|$ - metric tensor of the extended space. The stress tensor was recorded as:

$$\|F_{ik}\|=\begin{pmatrix} 0 & -E_x & -E_y & -E_z & -Q \\ E_x & 0 & -H_z & H_y & -G_x \\ E_y & H_z & 0 & -H_x & -G_y \\ E_z & -H_y & H_x & 0 & -G_z \\ Q & G_x & G_y & G_z & 0 \end{pmatrix}, \tag{5}$$

where the elements with indexes $i,k=0,1,2,3$ correspond to components of stress tensor of an electromagnetic field in 4-D space-time. Vector $\vec{G}=(G_x,G_y,G_z)$ and scalar Q are additional components.

In the element of energy-momentum-mass tensor, which associated with density of energy, are added additional members G^2 and Q^2:

$$T^{00}=\frac{1}{8\pi}(E^2+H^2+G^2+Q^2). \tag{6}$$

Modified vector of the momentum density looks as:

$$\vec{P}=\frac{1}{c}(T^{01}+T^{02}+T^{03})=\frac{1}{4\pi c}([\vec{E},\vec{H}]-Q\cdot\vec{G}). \tag{7}$$

Poynting vector of a field is expressed through vector of a momentum as $\vec{S}=c^2\vec{P}$.

Vector of the current constructed in the paper [8]:

$$\vec{\rho}=(\rho,\vec{j},j_s), \tag{8}$$

where $\rho,\vec{j}$ are densities of electric charge and current, j_s is additional component, corresponds to coordinate s.

In present paper we will turn to account formalism allowing separation electric charge from mass. It consists in assumption that if massive particle moves in fifth dimension with light velocity his electric charge is stationary in this dimension. But in 4D mass and electric charge of the particle have the same coordinates. Introduction of this formalism is conditioned, first, by necessity of fulfillment of the Maxwell equations and, secondly, by necessity of an absence of electric current in the open form in the given below equation (15), defined gravitation law, since otherwise presence of stationary in 4D electric charge influences on gravity. Such assumption does not contradict to the Kaluza-Klein theory and may be considered as version of ESM.

By means of the stress tensor (5) and the vector of the current extended Maxwell equations have been obtained in [8]:

$$div\vec{H} = 0, \tag{9}$$

$$rot\vec{E} + \frac{1}{c}\frac{\partial\vec{H}}{\partial t} = 0, \tag{10}$$

$$rot\vec{G} + \frac{\partial\vec{H}}{\partial s} = 0, \tag{11}$$

$$\frac{\partial\vec{E}}{\partial s} + \frac{1}{c}\frac{\partial\vec{H}}{\partial t} + gradQ = 0, \tag{12}$$

$$div\vec{E} + \frac{\partial\vec{Q}}{\partial s} = 4\pi\rho, \tag{13}$$

$$rot\vec{H} - \frac{\partial\vec{G}}{\partial s} - \frac{1}{c}\frac{\partial\vec{E}}{\partial t} = \frac{4\pi}{c}\vec{j}, \tag{14}$$

$$div\vec{G} + \frac{1}{c}\frac{\partial\vec{Q}}{\partial s} = 4\pi j_s. \tag{15}$$

Vector $\vec{G}$ in [4] is related to gravitation field and it is necessary to note, that in the equation (15) the only mass current j_s is included, since otherwise a stationary electric charge in 4D would influence on gravity. As components of the stress tensor have to be identical we set vector $\vec{G}$ as :

$$\vec{G} = q\vec{V}, \tag{16}$$

where $\vec{V}$ is the stress vector of the gravitation field, q is a constant having dimension $[q] = [mass]/[electriccharge]$.

In the present work we will determine the field Q by the following expression:

$$Q = 4\pi c\gamma q \int_{t_0}^{t} \mu(t, x, y, z, s)dt, \tag{17}$$

where γ is gravitational constant, μ is mass density, t_0 is a constant of time. Introduction of field Q in this generalize form is conditioned by the demand that Newton gravity has to be a particular case with substitution one in equation (15). In this interpretation field Q bears a relation to mass but this component of stress tensor has not a direct connection with mass, since we take derivative of Q with respect to time.

Current density j_s we assume to be null, which describes absence of the electric charges movement along the fifth coordinate. Let us consider example of field when electrical and magnetic components of the stress tensor are default, current vector and potentials are the following:

$$\vec{\rho} = 0,\ \varphi = 0,\ \vec{A} = 0$$

$$A_s = qW + 2\pi c\gamma q \int \int_{\tau_0}^{\tau(t)} \mu(x,y,z) d\tau(t) dt + C, \tag{18}$$

where W is a gravitational potential that expressed through vector $\vec{V}$ as: $V_i = \frac{\partial W}{\partial x_i}, i = 1,2,3$, τ is a proper time in the point $X = (x,y,z)$, τ_0 and C are constant. We take W to be independent from time and fifth coordinate s. Introduction of coordinate time in point X is conditioned by the fact that field Q (17) is depended from time, which of course may differentiate in points X_0 and X [17]. Here point X_0 sets down as a center of the coordinate system.

Thus the system of extended Maxwell equations gives only non-vanish equation (15), which taking into account (16) turns out to be

$$div\vec{V} + 4\pi\gamma \frac{\partial \tau}{\partial t} \mu(x,y,z) = 0. \tag{19}$$

With $\tau = t$ that means an equality of proper and coordinate time, this equation is transformed to the well-known Poisson equation for gravitation field.

Let us employ this approach for the analysis of the Pioneer-effect. NASA launched Pioneer 10 on March 1972 towards distant planets of the solar system. Radiometric data shows that additional acceleration takes place in direction of the Sun [18, 19, 20]. In [21] the constant component of this acceleration is considered as manifestation of non-orthogonal metric of five-dimensional space-time.

As was noticed earlier we don't consider a case when massive particle in 5D is stationary in space and has a rest mass, and its motion consists with non-zero 5D interval:

$$(ct)^2 - x^2 - y^2 - z^2 - s^2 = const > 0. \tag{20}$$

However, we note that in gravitational field the photon velocity is less then light velocity and this mathematically gives a nonzero value of the 5D interval in (20) for describing the movement in this field [9, 10]. Then for explanation of constant component of Pioneer 10 anomalous acceleration existence in framework of ESM the approach described in [21] is allowed, since non-zero 5D interval is considered for metric introduced here. This possibility will be a subject of our further research. Review of theories that explained an existence of the additional acceleration is contained in [19, 20]. Taking into account type of the Pioneer 10 mission it is possible to consider as trustworthy the data from 1987 to 1999 years [19], when its distance to the Sun was increased from 40 to 60 AU. In work [22] variable component observed additional acceleration is related with periodic change of a velocity of Pioneer 10 in relation to the Earth, which is caused by its movement around the Sun. Velocity of the Pioneer 10 in relation to the Earth v approximately determined by the expression

$$u = u_P + u_E cos(\nu t + \varphi_0), \tag{21}$$

where $u = v/c$, $u_P \approx 4.13 \times 10^{-5}$ corresponds to the Pioneer 10 velocity in relation to the Sun and $u_E = 9.97 \times 10^{-5}$ corresponds to the orbital Earth velocity, $\gamma = 2\pi$ 1/year, φ_0 is a constant.

Thus the Pioneer 10 proper time in Earth's center coordinate system neglecting terms containing u of higher orders of magnitude will be

$$\tau = (1-u)t. \tag{22}$$

Taking in account this relation the equation (19) has a solution in a form of a potential in point (x_P, y_P, Z_P):

$$W = (1-u)\gamma \int \frac{\mu d\Omega}{\sqrt{(x-x_P)^2 + (y-y_P)^2 + (z-z_P)^2}}, \tag{23}$$

where $d\Omega$ is volume element. This potential can be rewritten as:

$$W = (1-u)\gamma \frac{M}{r}, \tag{24}$$

where M is Sun's mass, r is a distance from the Sun to the Pioneer 10. By comparison with Newton gravity obtained potential gives additional acceleration

$$\hat{a} = u\gamma \frac{M}{r^2}, \tag{25}$$

to the massive particle with a radial movement.

It may be made still one supplementary prediction following from ESM on additional acceleration originated from $u_P = 4.13 \times 10^{-5}$ taking into account (21) and (24). But its value will be smaller by an order than the full acceleration (25).

We obtain from the equation (25) that amplitude of the oscillation of periodic component of the velocity (21) u_E has the amplitude of additional variable acceleration $|a_P^E| = 3.7 \times 10^{-8}$ cm/s^2 at the distance $r = 40$ AU and $|a_P^E| = 1.6 \times 10^{-8}$ cm/s^2 at $r = 60$ AU. For the Pioneer 10 this amplitude determined from measurements [19] amounts correspondingly to $|a_P^E|_{40AU} = (2.9-2.4) \times 10^{-8}$ cm/s^2 and $|a_P^E|_{60AU} = (1.3-0.8) \times 10^{-8}$ cm/s^2.

Thus, we considered (1+4) generalization of classical electrodynamics including gravitation field. With this approach it is assumed a presence of an extra component of extended field stress tensor, whose physical interpretation is based on necessity to obtain Newton gravity law as particular case.

In this work we have analyzed model where mass of having in 4D a rest mass particle moves in five-dimensional space-time along fifth coordinate with light velocity and its electric charge is a stationary value in additional dimension. Generalized gravity law that was obtained from extended Maxwell equations confirmed by existence of variable component of Pioneer 10 additional acceleration, whose analyze was made in frame of this model.

References

[1] D.Yu. Tsipenyuk, V.A. Andreev, *Krattkie Soobstcheniya po Fizike*, No **6**, 23-34, (2000)(*Bulletin of Lebedev Physics Institute (Russian Academy of Sciences)*, No.6, 18-29, Alerton Press, Inc., N.Y.,2001); gr-qc/0106093 .

[2] D.Yu. Tsipenyuk, V.A. Andreev, *Issledovano v Rossii* (Russian electronic journal),**60**, (1999); http://zhurnal.ape.relarn.ru/articles/1999/060.pdf

[3] D.Yu. Tsipenyuk, V.A. Andreev, "Structure of Extended Space", *preprint IOFAN* No. **5**, Moscow, (1999).

[4] D.Yu. Tsipenyuk, "Field transformation in the extended space model: prediction and experimental test", *Gravitation and Cosmology*, Vol. **7**, No.**4**(28), 336-338, (2001); physics/0203017 .

[5] D.Yu. Tsipenyuk, *Krattkie Soobstcheniya po Fizike*, No **7**, 39-49, (2001) (*Bulletin of Lebedev Physics Institute (Russian Academy of Sciences)*, Alerton Press, Inc., N.Y.,2002); physics/0107007 .

[6] D.Yu. Tsipenyuk, V.A. Andreev, *Krattkie Soobstcheniya po Fizike*, No **6**, 3-15, (2002) (*Bulletin of Lebedev Physics Institute (Russian Academy of Sciences)*, Alerton Press, Inc., N.Y.,2003); physics/0302006 .

[7] D.Yu. Tsipenyuk, *Issledovano v Rossii* (Russian electronic journal),**81**, 907-916, (2001); http://zhurnal.ape.relarn.ru/articles/2001/081.pdf

[8] D.Yu. Tsipenyuk, V.A. Andreev, "Electrodynamics in Extended Space", *preprint IOFAN* No. **9**, Moscow, (1999).

[9] D.Yu. Tsipenyuk, V.A. Andreev, "Gravitational effects in Extended Space", *preprint IOFAN* No. **4**, Moscow,(2001).

[10] D.Yu. Tsipenyuk, "Transformation of an Electromagnetic field into gravitational field in the model of Extended space: prediction and possible experimental check", *preprint IOFAN* No. **5**, Moscow, (2001).

[11] D.Yu. Tsipenyuk, "Electro-gravity interaction in the Extended space" , Russian National conference "Physics of Fundamental Interacting", 27 Nov.-1 Dec. 2000, ITEP, Moscow, http://www.itep.ru/ .

[12] P.S. Wesson and S.S. Seahra, Null geodesics in five-dimensional manifolds, *Gen. Rel. Grav.*, **33**, 1731 (2001); gr-qc/0105041.

[13] J. Van Dongen, Einstein and Kaluza-Klein particle, gr-qc/0009087.

[14] D.Yu. Tsipenyuk, V.A. Andreev, "Interval as the fifth coordinate" proc. of 5-th Int. Conf. on Gravitation and Astrophysics of Asian-Pacific Countries, PFUR, Moscow, 2001, 29-30.

[15] D.Yu. Tsipenyuk, "Model of extended space: Prediction and test experiments on possible transformation of electromagnetic field into gravitational field", proc. of XVIth Workshop on High Energy Physics and Quantum Field Theory (QFTEP), Moscow, Russia, 2001, pp. 398-405. http://theory.sinp.msu.ru∼qfthep/2001/Proceed2001.html

[16] D.Yu. Tsipenyuk, "Model of extended 5-d space and possible checking experiments", presented at 5-5h Moscow international ITEP school of physics (30-th ITEP winter school of physics), 20-28 Febr., Moscow, 2002, http://www.itep.ru/ .

[17] L.D. Landau, E.M. Lifshits, "Theory of field",2, 84, Moscow, Nauka (1973).

[18] J.D. Anderson, P.A. Laing, E.L. Lau, A.S. Liu, M.M. Nieto, S.G. Turushev, Indication from Pioneer 10/11, Galileo, and Ulysses data, of an apparent anomalous, weak, long-range acceleration, *Phys. Rev. Lett.* **81**, 2858 (1998), gr-qc/9808081.

[19] S.G. Turushev, J.D. Anderson, P.A. Laing, E.L. Lau, A.S. Liu, M.M. Nieto, The apparent anomalous, weak, long-range acceleration of Pioneer 10 and 11, XXXIV-th Rencontres de Morion Meeting on Gravitational Waves and Experimental Gravity 1999, Les Arcs, Savoi, France, gr-qc/9903024.

[20] J.D. Anderson, P.A. Laing, E.L. Lau, A.S. Liu, M.M. Nieto, S.G. Turushev, Study of anomalous acceleration of Pioneer 10 and 11, *Phys. Rev.* **D65**, 082004 (2002), gr-qc/0104064.

[21] W.B. Belayev, Cosmological model with movement in fifth dimension, *Spactime and Substance* **7**, 63 (2001), gr-qc/0110099.

[22] W.B. Belayev, Five-dimensional gravity and the Pioneer effect, gr-qc/0209095.